Art. VI.—*Memoranda relative to experiments on the communication of Telegraphic Signals by induced Electricity.—By* W. B. O'Shaughnessy, M. D. *Assistant Surgeon; Professor of Chemistry, Medical College, Calcutta; and Officiating Joint-Secretary to the Asiatic Society of Bengal.*

There are few projects which at first sight appear so visionary as those which promise practical benefit to mankind through the agency of electrical operations. From the dawning of knowledge in this science, pretenders of every grade have found it a free field for their speculations: and hence perhaps it arises that the sober and practical part of society generally regard with distrust, the multitudes of projects which electricians are constantly advancing.

We nevertheless find that many eminent philosophers—whose habits of cautious research, have been proved by their numerous contributions to the mass of general science—such men as Brande, Faraday, Wheatstone, and Fox—are amongst the foremost, who predict many real advantages to the community from the application of the mysterious, though readily controllable forces which electricity places at our command.

I am aware that I am less entitled than many others to have my inferences from electrical data attended to with confidence, having at least on one occasion fallen into the error of indulging prematurely in dreams of useful results, and of reasoning unguardedly from the model to the machine. Still I believe that the experiments detailed in this paper, will be found to admit fairly of the consequences to which they seem to me to lead. They appear to me conclusive as to the perfect practicability of establishing, at a cheap rate, telegraphical communications, acting through electrical agencies, certain and infallible in their indications, perceptible alike by night and day, in all varieties of weather and season, and, lastly, so swift in their nature, that the greatest distances concerned bear scarcely any appreciable proportion to the inconceivably brief period in which the signal can be conveyed.

I was induced to institute the experiments detailed in this paper, by the statements I had read in several periodicals regarding similar attempts in England and the continents of Europe and America, and the actual patenting and adoption by the directors of the London and Birmingham railway of a similar plan by Professor Wheatstone, of the King's College, London.

Before entering into details regarding my experiments, which were carried on in the Botanical Gardens of Calcutta, during May of this year, it will perhaps prove interesting to give a rapid historical outline of the attempts which have been made to apply the various indications of the electrical fluid as the medium of instantaneous communication between distant places. For several of the following references I am indebted to an article by Dr. Steinheils of Munich, translated in the May number of Sturgeon's Annals of Electricity.

Historical Notice.

1.—*Telegraphs by common electricity.*

The first electrical telegraph on record was proposed by Winkler of Leipzic, in 1746. He employed a Leyden jar which was discharged through a single wire, a reach of the river Pleiss being included in the circuit. Le Monnier afterwards made a similar experiment in Paris, using a wire 12,789 feet long. In 1798, Betancourt laid a wire between Madrid and Aranjuez, 26 miles distant, to serve for the transmission of shocks by the Leyden phial. The pith ball electrometer was used by Lomand; and the sparks from tin-foil on glass surfaces by Reiser about the same period.

In 1826, Francis Ronalds, of Hammersmith, published a description of a plan in which two clocks were employed, one at each terminal station. Each clock had a moveable dial with twenty signals on its circumference. As the required signal letter presented itself, a spark passed at each station by the discharge of a Leyden phial. This plan, though comprising, as I will point out in the sequel, the true principle of a good system, was found useless in practice, as each sign was given but once in each revolution.

Such are the principal attempts hitherto made to effect the object in view, by means of frictional electricity. At the Meeting of the Asiatic Society of Bengal, of June 1839, M. Adolphe Bazin presented a project for effecting telegraphic correspondence by means of thirty insulated conductors passing between the terminal stations, each conductor representing a letter or number, so that by the rapid succession of sparks correspondence could be effectually carried on. With this M. Bazin connected an hydraulic apparatus for the conveyance of intelligence across rivers, and in other situations where frictional electricity might not be suitable.

M. Bazin's plans, although very ingenious, were altogether impracticable, and as we shall afterwards establish, demanded thirty conductors, where only one is actually requisite; moreover the impediments to the use of common electricity are absolutely insuperable in all countries (Bengal for example) visited by periodical rains or inundations.

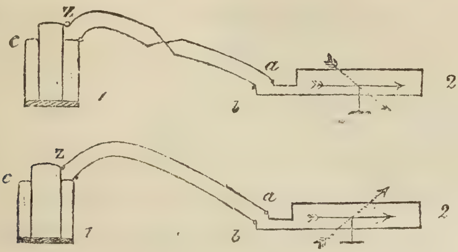
M. Bazin indeed admitted this freely, when he found that not one of the electrical machines I placed at his disposal could by ordinary manipulation be made to evolve the least sign of excitement. But even effecting the excitement, which I have done by enclosing the machines within a glass case hermetically sealed, and supplied with air artificially dried, still it is impossible so to insulate the *external* conductors, as to prevent the dispersion of the excitement outside the apparatus.

§ 2.—*Telegraphs by Chemical decomposition.*

In Steinheils' historical sketch we find that Soëmmering, in 1807, employed a voltaic battery provided with thirty-five conductors, each terminating in a gold pin set in a tube; on completing the connexions the water is decomposed and the ascent of bubbles of gas indicates the signal. This system is, however, only available for very short distances, as the decomposing power of the termination of any pair of conductors, the diameter being the same, diminishes rapidly by lengthening the wire. The law of the diminution, Ritchie has attempted to establish, but his experiments are not considered to be conclusive; its rapidity may be shewn by an experiment I performed in 1839. A voltaic battery, the conductors of which were *six* feet long, decomposed water to the rate of forty cubic inches of oxygen and hydrogen gases in three minutes. Conductors of the same diameter, but *thirty-six* feet long were next employed; the battery then only evolved twenty-five cubic inches of the gases; with wires of 200 feet only eleven inches were obtained; still the battery was constant in its action, for with the original conductors at the close of the experiments it still gave forty cubic inches. Again in the experiments at the Botanical Garden in 1839, no chemical decomposition—even of the most yielding of all compounds, the ioduret of potassium—could be performed at the termination of one and a half miles, whereas other manifestations of electrical action were readily procurable at the termination of twenty-one miles of wires.

§ 3.—*Telegraphs by volta-magnetic deflection.*

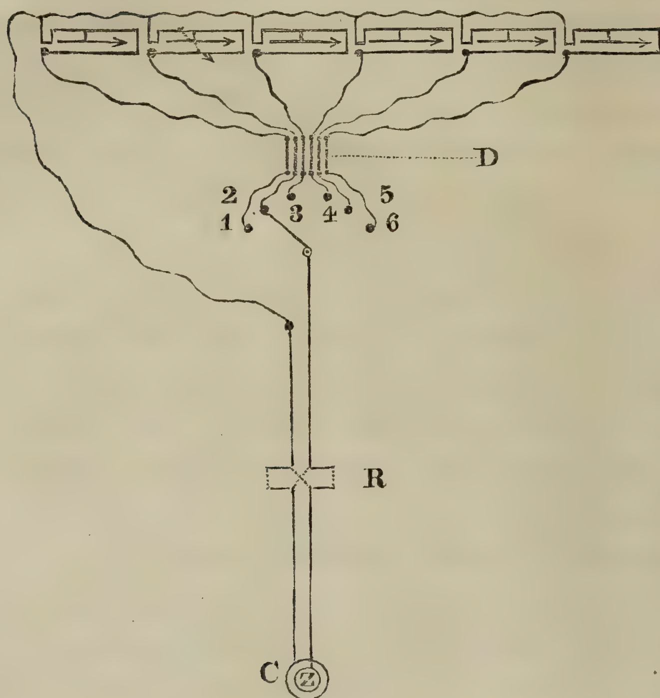
The next method employed is the deflection of the magnetic needle by voltaic or magnetic electricity. I may remind the general reader that whenever electrical vibrations occur in exceedingly rapid intervals in an insulated wire surrounding and in the same direction with a balanced magnetic needle, the needle is deflected, either east or west according to the order in which the ends of the surrounding coil are connected with the source of electrical excitement. As I am now writing for popular readers I may be pardoned by the adept for illustrating this interesting fact by an explanatory diagram.



In this diagram, 1 represents the voltaic couple; *z* zinc; and *c* copper; 2 shews the magnetic needle on its stand in the magnetic meridian, with the surrounding coil of wire, with its terminations *a* and *b*. In the first the wires cross, or that from *z* proceeds to *b*, that from *c* to *a*, and the deflection accordingly is from north to west. In the second the wire from *z* proceeds to *a*, that from *c* to *b*, and deflection of the needle is from north to east.

Thus with two wires we can obtain two signals only, but one wire may belong, or be common to any number of galvanometers, so that from three wires we can obtain four signals; from four wires six signals; from five wires eight signals; from six wires ten signals; eight wires fourteen signals; ten wires eighteen signals; twelve wires twenty-two signals; fourteen wires twenty-six signals, or the alphabet.

In the following diagram six galvanometers are represented connected with seven wires, one being common to all. The six wires run any distance in a bundle, and are best insulated by silk or resin from each other. The ends of the wires then proceed to little cisterns of mercury, disposed in a circle. From the centre of the circle a moveable wire proceeds as a radius, which may be moved to any of the cisterns 1, 2, 3, 4, 5, 6. To this centre proceeds one of the poles (*z*) of the voltaic couple—and to the termination of the common wire, proceeds the second pole of the couple *c*.



In the diagram the connexion is made with No. 2, and the dotted line shews the deflection of the needle—and this deflection may be reversed by crossing the course of the battery wires, as shewn at R. The five parallel lines at D shew the conductors, which may be indefinitely prolonged.

Thus by a move of the *radius wire* to any of the cisterns we can deflect the needle at the corresponding galvanometer; and by a move of the cross wires we can reverse the deflection at our pleasure.

We have here a combination which affords sufficient numbers for spelling, numbering, dictionary and cypher signals. Even four galvanometers which can be worked by five wires, will afford the necessary combinations for every description of signals.*

* This telegraph has been actually laid down between London and Drayton, and i- to be carried on to Bristol. Though extremely ingenious, I shall presently prove that the railway itself without any special conductors, or at most with one wire, is a perfect telegraphic line.

In Davy's telegraph the needles carry slight screens which conceal illuminated letters or numbers—on deflecting the needle the signal is disclosed.

Soon after the discovery of the deflection of the needle, several attempts were made to establish by its use, the laws of action of the battery. Ritchie attempted to prove that the deflection was in the direct ratio to the surface of zinc acted on in the battery. Thus supposing the conductors unchanged, and that by the corrosion of one superficial inch of zinc a deflection, say of 5° be obtainable, the corrosion of two superficial inches will give a deflection of 10°. Were this assertion supported, a single galvanometer would give us all the signals we could require. It is now however proved that the supposed law by no means holds good. It is quite true that we may double or treble a given deflection, or that we may by direct experiment proportion the voltaic force to the deflection required, but such experiments are only fit for performance in the closet or laboratory,—require such careful adjustment and observation—and are, moreover, so exceedingly delicate, and take so much time in recording, that they become quite unsuitable for the rapid transmission of telegraphic signals.

In the preceding arrangements in which several galvanometers were used, we have manifestly all that we require within the distances to which experiment has yet reached. But the expense of wire next presents itself as a motive for endeavouring to improve the system by diminishing the number of the wires. To render this intelligible, of the copper bell wire best suited for these experiments, each mile costs 276 rupees.

Steinheils of Munich, the most recent writer on this subject, proposes either of two very ingenious methods. The first is causing the galvanometrical needle to terminate in a fountain pen, the tip of which touches and marks a strip of paper revolving by clockwork;—according to the number of dots a letter or numerical signal can be obtained. The second plan is the employment of the tip of the needle to strike a bell, when the number of strokes in a given time afford the requisite signal.

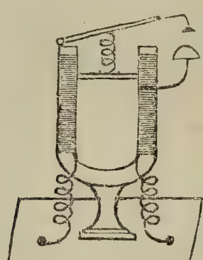
The galvanometer moreover has been rendered so exceedingly delicate in its indications, that very feeble electrical forces will succeed in producing deflections. The electricity evolved by holding up the hand before a disk composed of bismuth and antimony, caused in an instrument contrived by Dr. Page, of Baltimore, a deviation of fifty degrees. In a galvanometer in my possession, constructed by Messrs. Watkins and Hill, the action of a drop of acidulated water on a zinc wire the size of a pin, and opposed to a copper element of equal size, urges the needle through a quarter of a circle. Moreover the differential principle so successfully applied by Häuy to the discovery of magnetism in minerals containing traces of iron, can be had recourse to here so as to enhance still further the delicacy of these beautiful instruments.

Having thus sufficiently exposed the construction and mode of action of the galvanometer, I must reserve for another place, the results of my experiments in testing the value of the different methods described.

§ 4.—*Henry's Magnetic Telegraph.*

I have still however to notice another proposal which has attracted great attention, and is said, on good authority, to be in course of practical application in the United States.

Professor Henry proposes to employ the sudden development of magnetism, occasioned in a horse shoe bar of soft iron while surrounded by a spiral of insulated wire, the extremities of which are in contact with a voltaic couple. The magnet thus created attracts a light piece of iron which carries an arm. The arm when attracted marks dots on a revolving cylinder, or may strike a bell. The arrangement is shewn in the following figure. The spiral wire in the centre is a spring to lift up the arm on the cessation of each stroke.

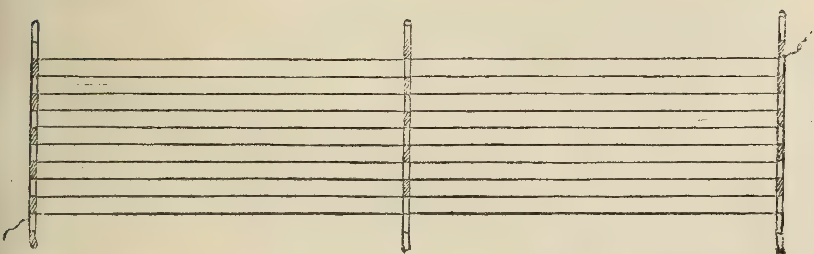


Eleven miles of wire were employed in one of Henry's experiments, but the wire was coiled spirally round a drum, a circumstance which considerably invalidates the results. This will seem sufficiently intelligible by reference to the construction of the " coil electro-magnetic machine," described in a subsequent page.

§ 5.—*Experiments by the Author.*

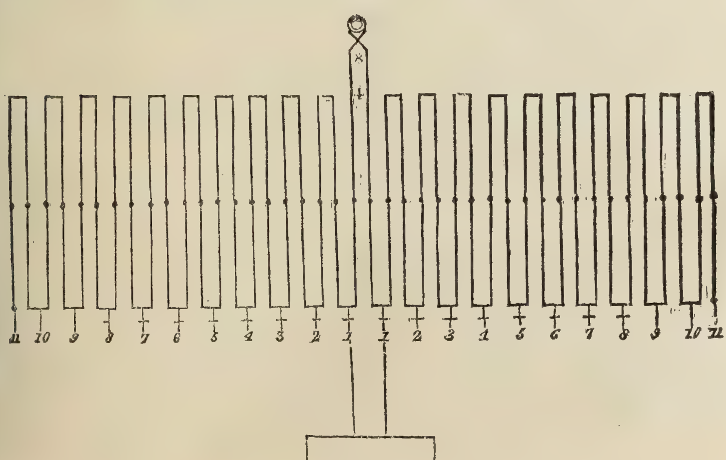
I have now given an adequate sketch of the several methods of communication hitherto proposed, and I proceed to the description of the experiments I have carried on, in the view of testing the comparative merits of the preceding plans and of another, which I have myself devised.

My first object was to construct a line of wires of sufficient length to afford practically valuable results. With Dr. Wallich's liberal aid a parallelogram of ground, 450 feet long by 240 in breadth, was planted with forty-two lines of bamboos. Each line was formed of three bamboos firmly driven into the ground, fifteen feet in height. Each row was disposed so as to receive half a mile of wire in one continuous line, thus,*



The strands of wire were one foot apart from each other. As each row was laid down, it was carefully coated with tar varnish.

A tent was pitched in front of the entire line, and the connections of the wires were so established that in the course of half an hour it could be tested from centre to the extreme flank, so as to ascertain the effects of lengths of wire, varying from one to eleven miles at either side, forming a total circuit of twenty-two miles. This may be perhaps more readily intelligible from the subjoined figure.



* Eleven lines should have been shewn in this drawing.

The cross lines above the numbers exhibit the wires led from each half mile of conductor. Thus by cutting through 1. 1. the next numbers to right and left became the conductors or nearest electrodes, and the length of the circuit thus rose from one to three miles; cutting 2. 2. will make 3. 3. the electrodes, and increase the circuit to five miles, and so on, each section added a mile to the circuit at either side.

The wires employed were of iron (annealed), diameter one-twelfth of an inch. It is almost needless to observe that iron was used not from choice but necessity. A sufficient quantity of copper wire was not procurable in Calcutta, no draw-bench was ready to manufacture the necessary supply, moreover the rainy season was fast approaching when such experiments could scarcely be attempted, constant exposure in the open air being essentially requisite to success. The expense again of copper would have amounted to much more than a private individual could afford.

With iron wire however I considered that the results would be still of much practical value. Being the *worst* of the metallic conductors of electricity, it seemed a reasonable inference that whatever might be found practicable with iron, would *à fortiori* be so with the copper, or best conductor.

On the completion of the line the following instruments were tried.

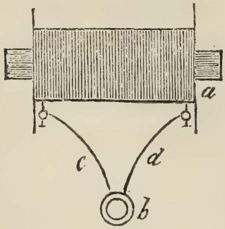
1st. An electro-magnet of soft iron, 1½ inch in diameter, poles 1 inch apart, length from centre to poles 12 inches, weight 14 lbs. surrounded by one hundred yards of insulated copper wire, the twelfth of an inch in diameter. This electro-magnet, when excited by the voltaic battery used in the subsequent experiments, with conductors seven feet in length, supported 240lbs.

2nd. An electro-magnet of very small size, constructed by Watkins, of London, capable of supporting 30lbs. with the battery now referred to, and with the same length of conductors.

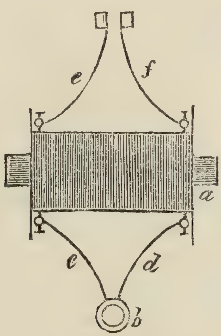
3rd. An astatic galvanometer by Watkins and Hill, already referred to.

4th. An electro-magnetic induction machine, also by Watkins, of which a brief description is desirable.

This instrument consists of a coil of thick wires insulated by silk, and wound spirally round a wooden cylinder having a hollow axis one inch in diameter. The ends of this coil are connected with metallic screws, so that they can be joined to the poles of a voltaic battery.



Around this primary coil is wound a second coil of extremely thin wire, also insulated and 1000 yards long, totally unconnected, though in close juxtaposition with the primary coil, the ends of the wire being led to screws to which handles, directors, &c., can be attached, thus,



Into the hollow axis at *a* is introduced a bundle of insulated iron wires.

The action of the instrument may be very briefly described. While the battery at *b* is in contact with the wires *c d* the primary coil is excited. By interrupting the circuit at + or elsewhere, at the instant of its interruption, the secondary or external coil becomes excited by induction or proximity—and this excitement is augmented by the influence of the magnetism simultaneously annihilated in the central bundle of iron wire.

The electrical state thus momentarily generated in the secondary wires, may be rendered evident by the production of a spark and shock, by effecting chemical decomposition and all the other signs of electrical action, at the terminations of the secondary coil *e, f.*

In this cursory description I confine myself to facts alone, and refrain from entering on any theoretical speculation as to the causes of these singular and deeply interesting phenomena.

Experiments with the Electro-magnet No. 1.

The day being fine, the ground and bamboos perfectly dry, at 9. A. M. the sustaining power of the electro-magnet No. 1. was tested with iron conducting wires ten feet long, and found to amount to 46 lbs.

With one mile of same wire, ½ mile at each side,

it supported, ...	18 lbs.
2 Miles of wire, ...	8 lbs. with difficulty.
3 Miles of wire, ...	2½ lbs.
4 Miles of wire, ...	23 ounces, with difficulty.
4½ Miles, ...	sustaining force ceased altogether.

Electro-magnet No. 2.

With 10 feet wire, ...	12 lbs.
—— 1 Mile, ...	7 lbs.
—— 2 Miles, ...	3 lbs.
—— 3 Miles, ...	0½ lb.
—— 4 Miles, ...	no sustaining power.

Assuming iron to be inferior to copper in about the proportion of 1 to 7, according to Sir Humphry Davy and Becquerel's standard of conductors, this experiment shews that for equal diameters of wire, copper would convey the signal by Henry's method to about twenty-one miles in an imperceptible period of time. This distance might be extended by enlarging the diameter of the wires, but to what limit, is as yet unknown.

Experiments with Galvanometer.

The astatic galvanometer was arranged and levelled with much care, the needles retaining a very slight degree of directive force so as to cause them to swing in the magnetic meridian.

At 1 Mile, deviation maximum or .. .. 90°

The needles being restrained by pins at the quadrant:—

At 2 Miles.	90°
— 3 Miles.	75°
— 4 Miles.	63°
— 6 Miles.	40°
— 10 Miles.	11°
— 11½ Miles at each side to total circuit 23 miles.	barely perceptible.

Up to the sixth mile the needles were deflected with great rapidity on the connexion being made with the voltaic element. The reversal of the order of connection also satisfactorily reversed the needle from east to west, and the contrary. But when the deflection fell to below 40°, the movements were exceedingly sluggish, so that on an average two seconds elapsed before each signal could be read off. The change of battery poles then often failed in reversing the direction of the needles—and here, as before, at least two seconds were consumed in each movement. Applying the same rule to this as to the preceding experiment, the galvanometer would convey signals by a copper wire to a distance of twenty-eight miles—and this might be increased by enlarging the wire or the battery, or by adding to the delicacy of the galvanometer—but in one essential point this system was deficient, namely, in rapidity of movement. Two seconds or even *one,* on each telegraphic movement, would be an extravagant waste of time compared with the celerity with which signals can be conveyed by another method.

Chemical decomposition.

One of the most delicate of all tests of voltaic electrical action is the decomposition of ioduret of potassium and the production of a blue colour which the free iodine strikes with starch. This effect was produced in my experiments for a line of three miles of wire. Beyond this no decomposition could be effected. From this fact we are entitled to infer the impracticability of Soëmmering's method. See § 2.

Induction machine, and mode of correspondence by Pulsations and Chronometers.

The battery was connected with the primary coil see fig. 1. p. 723. by very short wires;—the ends of the secondary coil wires screwed to the right and left wires of the great parallelogram. P. 721.

On breaking contact with the primary coil, a shock utterly intolerable passed at half a mile to an individual holding the metallic handles in which the wires ended.

To avoid fatiguing details I may at once state, that by this secondary coil, excited by but three small voltaic couples, the shocks up to seven miles were exceedingly smart—at eleven and a half at each side, they amounted to no more than strong, but not disagreeable, sensations. I think these might be best termed "pulsations," for to the *hand* they impart the same feeling proportionately, that a strong and full pulse does to the *finger*.

Each pulsation is practically simultaneous with the breaking of contact with the battery. To give a rude idea of the velocity of the signal, the contact being broken by a clicking wheel, on a perfectly calm morning, at a distance of but sixty yards, the pulsation was invariably felt at a sensible interval before the click which preceded it was heard. Thus sound travelling at the rate of 1090 feet in one second=to 121 feet in one-ninth of a second, the electrical impulse passes through a total circuit of twenty-two miles, in less than that practically insignificant fraction of time. This however conveys but an erroneous notion of the almost inconceivable velocity of the impulse. Professor Wheatstone has proved that the electrical accumulation of the Leyden phial is discharged and circulates through copper conductors, one fifteenth of an inch in diameter, with greater velocity than the progress of light through the planetary spaces, and in the rate at least of 288,000 miles in a second. Now the discharges of the Leyden bottle and those of induced coil electricity are in the closest circumstances analogous to each other.

Of the pulsations thus transmitted, it is perfectly easy to count six in one second—thus with a little practice any signal number can be made from one to six in one second.

Besides the simple repetition of the pulsations up to nine, beyond which they become indistinct for each signal, there are at least two modes of conveying other sensations by this apparatus. If the connexion between the battery of the primary coil be made and broken by a ratchet-wheel of brass and silver, and the wheel be turned pretty rapidly, a sensation analogous to the ruffle of a drum is so distinct as to render mistake impossible. A third set is obtained by interposing a flat file in the battery circuit, and interrupting this by drawing one wire along the surface of the file; here instead of the ruffle, the feeling is that of a blunt saw drawn lightly across the palms of the observer's hands. It is difficult to express in words the differences in these distinguishing signals, but the practice of a quarter of an hour will make the observer so familiar with them, that he can without the slightest difficulty carry on a communication by numbering or spelling with his distant correspondent. With a tithe of the practice of a pianist or harpist, the most perfect sympathy is practicable between the signalists, and that as fast as the signal can be spelt. In short, with but little less velocity than the articulations of language or the writing of stenographic characters, this silent, but thoroughly intelligible, and still most secret of all correspondence can take place.

It is almost unnecessary for me to remind the reader of the admitted fact, that the exquisite delicacy of the impressions of the touch transcends, in some respects, the evidence of all the other senses. The eye and ear are liable to distraction by casual sounds or phenomena, while the attentive touch knows no interruption. The eye must close momentarily and thus lose the observance of many rapid phenomena. Dazzled by too vivid lights, and confused by too constant watching, vision soon ceases to be accurate, while the frequent repetition of similar sounds either becomes absolute silence to the ear, or like the murmuring of a rivulet or the humming of insects, gradually narcotizes the observer. Let the experimentalist attempt to count but 200 rapid strokes of a faint bell, and he will at once acknowledge the imperfections of any acoustic method.

Thus with copper conductors equal in diameter to the iron wires I employed, signals by pulsation are proved to be communicable by the method above described, in less than any appreciable period of time, to the distance of 154 miles.

Besides the method of telegraphing by pulsations and other signals recognized by touch alone, there is another of which I have made extensive trial, and which is capable of affording still more accurate and intelligible and equally rapid results.

Without any knowledge of the experiments quoted by Steinheils—many months indeed before the paper by that author was published in England—I attempted, and with success, to effect the transmission of signals by using time-keepers at each terminus, and causing the pulsation to be felt as the hands simultaneously passed a certain number or letter on the dial.

In these experiments I first employed a pair of watches modified for my use by that ingenious artist Mr. Grant, of this city. All the movements were taken out but those connected with the second-hand, and a long lever was so constructed as to check the balance-wheel at pleasure during the recoil. Round the second-hand was placed a card dial laid off with three concentric circles divided each into twenty parts. Omitting vowels and superfluous letters, the alphabet was laid down in each circle so that the hand would during each revolution point to any letter three times; the compartments were moreover numbered on the same principle, so that each figure from one to ten would be pointed to six times in a revolution.

The hand is passing each compartment during three seconds. The observer receives say two pulsations, and is thereby referred to the second circle, and reads the letter or cypher, according as the signal be for spelling or numbering.

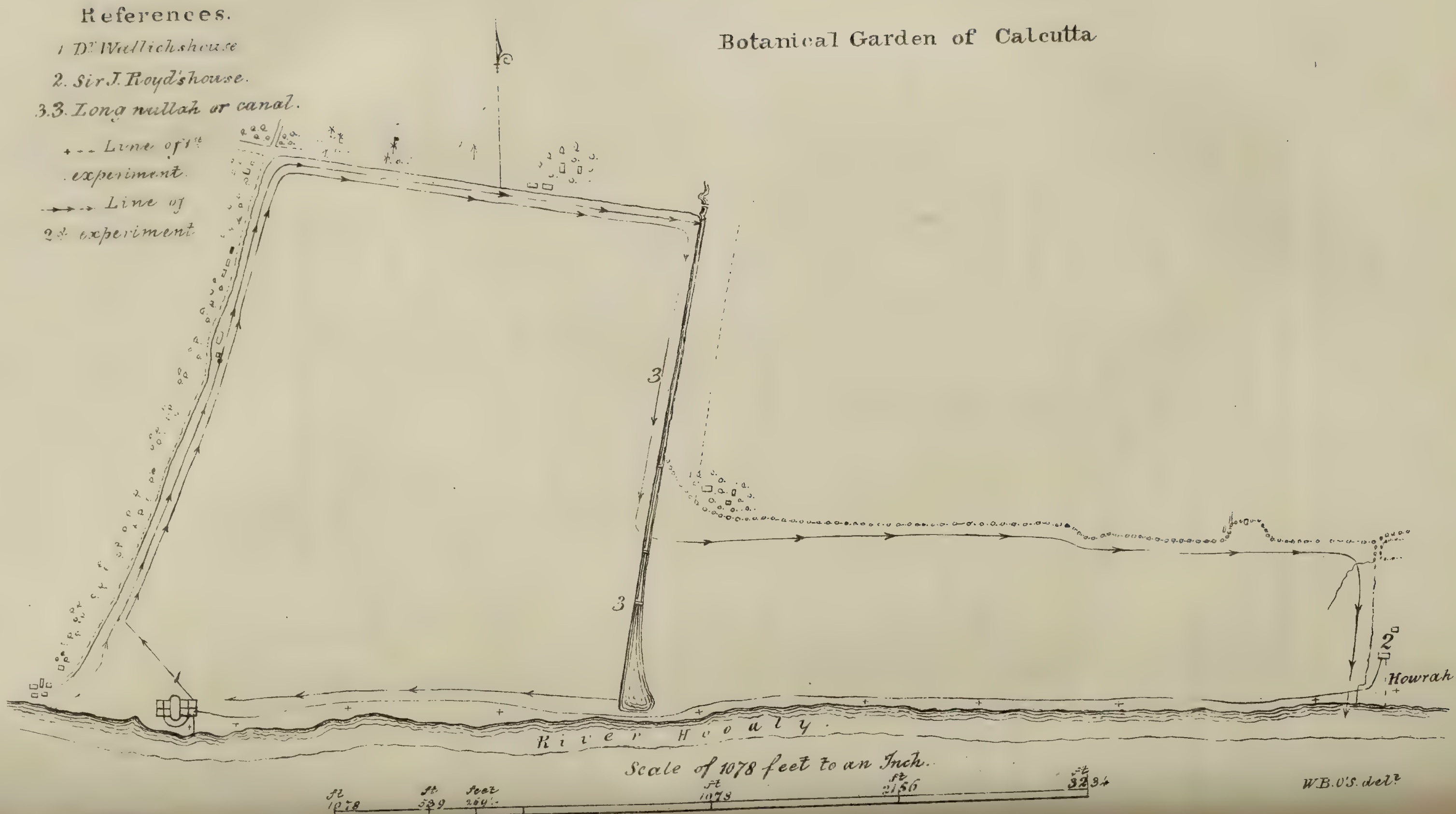
Although the watches were of the very cheapest kind, and would not keep time together for more than five minutes, still they were quite sufficient to enable a correspondence to be carried on. Thus a signal seldom lasted longer than three minutes; both watches were then allowed to run to No. 1 or zero, and stopped. To renew correspondence a prolonged roll was communicated. If but one roll, it indicated spelling; if two, numbering. On the roll ceasing, three pulsations at intervals of one second were passed, and at the third the correspondents started their watches.

The pendulum was also tried, and with decided advantage. Two German clocks sufficed to demonstrate the practicability of the system. The striking parts were removed, and also the hour and minute hands and dial.—To the axis of the escapement wheel a needle was attached, carrying a light hand which indicated on a dial the signals above described. The German clocks (which cost but 16 rupees the pair,) in numerous experiments beat together for several hours, and could always be relied on for one hour at least. It is almost needless to add, that by shortening or lengthening the pendulum the rate was readily varied from 40 to 80 seconds for each revolution.

I did not omit chronometers, although I could not of course so alter these costly instruments as to adjust them perfectly to my experiments. It is obvious however that chronometers will on my method give an unerring and constant mode of telegraphic correspondence. In a recent trial at Greenwich the mean error of several instruments in one year was but two seconds!* Here then are two movers constantly and simultaneously pointing to one and the same signal, be it letter, figure, or cypher. The electric pulsations which "take no note of time" or distance, supply us with the means of converting this synchronism to the unexpected and invaluable end to which it is now proposed to be applied.

Even employing inferior chronometers, the addition of a moveable dial which could be adjusted daily on a method too simple to need description, would secure the perfection of the correspondence; or the daily difference of the instruments being known, a tabular correction could we made; or, lastly, by an occasional astronomical observation of true time at each station, the object in view could be as certainly obtained.

* In 1831, the first three prize chronometers only differed $\frac{19}{100}$ of a second in one year.



Electrotelegraphic Signals conveyed by Water.

§ 6.—*Water a conductor of Pulsation Signals.*

During the preceding series of experiments, I had ample proof of the great conducting power of water for this form of electrical impulse. Shocks or strange thrilling sensations were perceptible at every step while proceeding through the ground, as long as the morning continued damp. When, however, the sun became sufficiently powerful to dry up the dew, and remove the film of water from the wires, bamboos, and grass, then the wires alone conveyed the electricity. My experiments convince me that dry wood, earth, and masonry are perfect non-conductors of this kind of excitement. Even the bark of living trees seems a perfect insulator.

Some months previous to the experiments now described, I accidentally found too (by the falling of a wire into the large tank at the Medical College) that when water was available, only one insulated wire was requisite for completing communications. I did not omit the opportunity afforded by my experiments at the Gardens of following up this curious result, and although I find the fact has also attracted the attention of Professors Henry and Steinheils, these philosophers will, I feel convinced, learn with interest the simultaneous pursuit of the like object, in my humble investigations.

In one experiment the electro-magnetic machine was stationed at the ghât of Bishop's College, and one of its wires, but twenty-five feet long, dipped in the Hooghly at the ghât. The second wire ran along the dry path round through the Botanic Gardens, and terminated in Dr. Wallich's library. A wire led from the river at the ghât before Dr. Wallich's house, also into the library. The assistant stationed at the machine was directed to make the signals in the usual manner. Every signal told in the library without any notable diminution of effect.

It made no perceptible difference whether the tide was ebbing or flowing ;—in several trials the damp mud even conveyed the signal unaltered in force or character.

The distance by water in the above experiment was 7,000 feet. In a second set of trials the machine was placed at Sir John Royd's garden, the water distance intervening being 9,700 feet, and with the same results as before. (*See lithographed plan No.* 1.)

In a third trial, seven miles of wire were disposed round the trees of the Garden, taking in its entire boundary—starting from Dr. Wallich's house and terminating in the river at Howrah ; a second wire was carried from the river, at the west end of the Garden (two miles